

Punch-through jets in $A + A$ collisions at RHIC/LHC

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Abstract. High p_T single and dihadron production is studied within a NLO pQCD parton model with jet quenching in high energy $A + A$ collisions at the RHIC/LHC energy. A simultaneous χ^2 -fit to both single and dihadron spectra can be achieved within a narrow range of energy loss parameter. Punch-through jets are found to result in the dihadron suppression factor slightly more sensitive to medium than the single hadron suppression factor at RHIC. Such jets at LHC are found to dominate high p_T dihadron production and the resulting dihadron spectra are more sensitive to the initial parton distribution functions than the single hadron spectra.

A strongly coupled quark gluon plasma (sQGP) is now believed to exist in high energy nucleus-nucleus collisions with a large volume and a long life time. Such dense matter can be probed by the quenching[1] of high transverse momentum p_T partonic jets which will lose a significant amount of their energy via induced gluon radiations when propagating through the dense matter. The energy loss is predicted to lead to strong suppression of both single- and correlated away-side dihadron spectra at high p_T [2, 3], consistent with experimental findings [4, 5].

The suppression factor of the leading hadrons from jet fragmentation will depend on the total parton energy loss which in turn is related to the jet propagation path weighted with the gluon density ρ_g along the propagation path [2]. A simultaneous fit to the single and dihadron data constrains the energy loss parameter within a narrow range: $\epsilon_0 = 1.6 - 2.1$ GeV/fm [3]. The fact that both χ^2 's in Figure (1) reach their minima in the same range for two different measurements provides convincing evidence for the jet quenching description. At the RHIC energy, the high p_T dihadrons are found to come not only from jet pairs close and tangential to the surface of the dense matter but also from punch-through jets originating from the center of the system while the high p_T single hadrons are only dominated by jets emitted perpendicularly near the surface of the overlap in Figure (2). Consequently, the dihadron spectra is slightly more sensitive to the initial gluon density than the single spectra.

Punch-through jets are significant for dihadron production not only at the RHIC energy but also at the LHC energy. Shown in Figure (3) are the spatial transverse distributions of the initial parton production points that contribute to the final high p_T

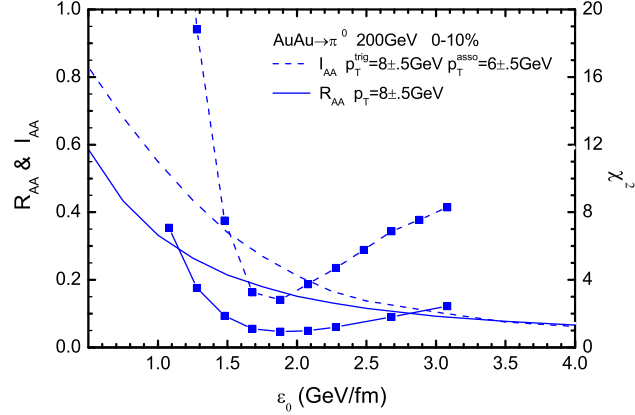


Figure 1. The suppression factors for single (R_{AA}) and dihadron (I_{AA}) spectra at fixed transverse momentum as functions of the initial energy loss parameter ϵ_0 . Also shown are χ^2 's (curves with filled squares) in fitting experimental data on single ($p_T = 4 - 20$ GeV/c) and away-side spectra ($p_T^{\text{trig}} = 8 - 15$ GeV, $z_T = 0.45 - 0.95$) in central $Au + Au$ collisions at $\sqrt{s} = 200$ GeV.

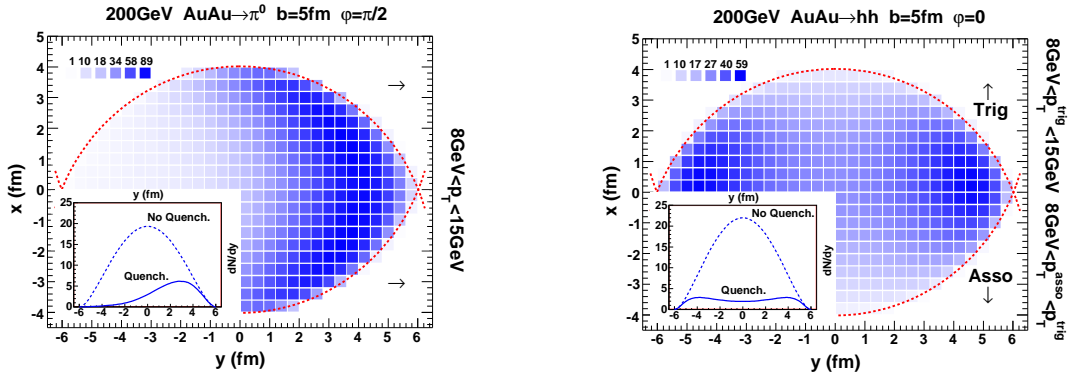


Figure 2. Spatial transverse distribution (arbitrary normalization) of the initial parton production points that contribute to the single and dihadron along a given direction at RHIC. The insert is the same distribution projected onto the y -axis.

single and dihadron at the LHC energy. The jets contributing to the single hadron at LHC still have a surface emission bias similar to the RHIC case in Figure (2). However, the fraction of dihadron yield from punch-through jets is found to increase with the transverse momenta of dihadron at the LHC energy. Such difference in the geometry of the single hadron and dihadron production will result in some interesting phenomena.

Shown in Figure (4) are the single and dihadron suppression factors in central $Au + Au$ collisions with 4 kinds of shadowing parameterizations, EKS98 [6], nDS [7], nPDF [8], Hijing [9]. Among the 4 sets of suppression factors, R_{AA}/I_{AA} at RHIC/LHC, only the dihadron suppression factor I_{AA} at LHC is found to be sensitive to different shadowing parameterizations. Initial partons participating in strong interaction in the central region should be associated with stronger shadowing effects than those initial partons in the outer layer of the system. Because of surface emission bias, the single

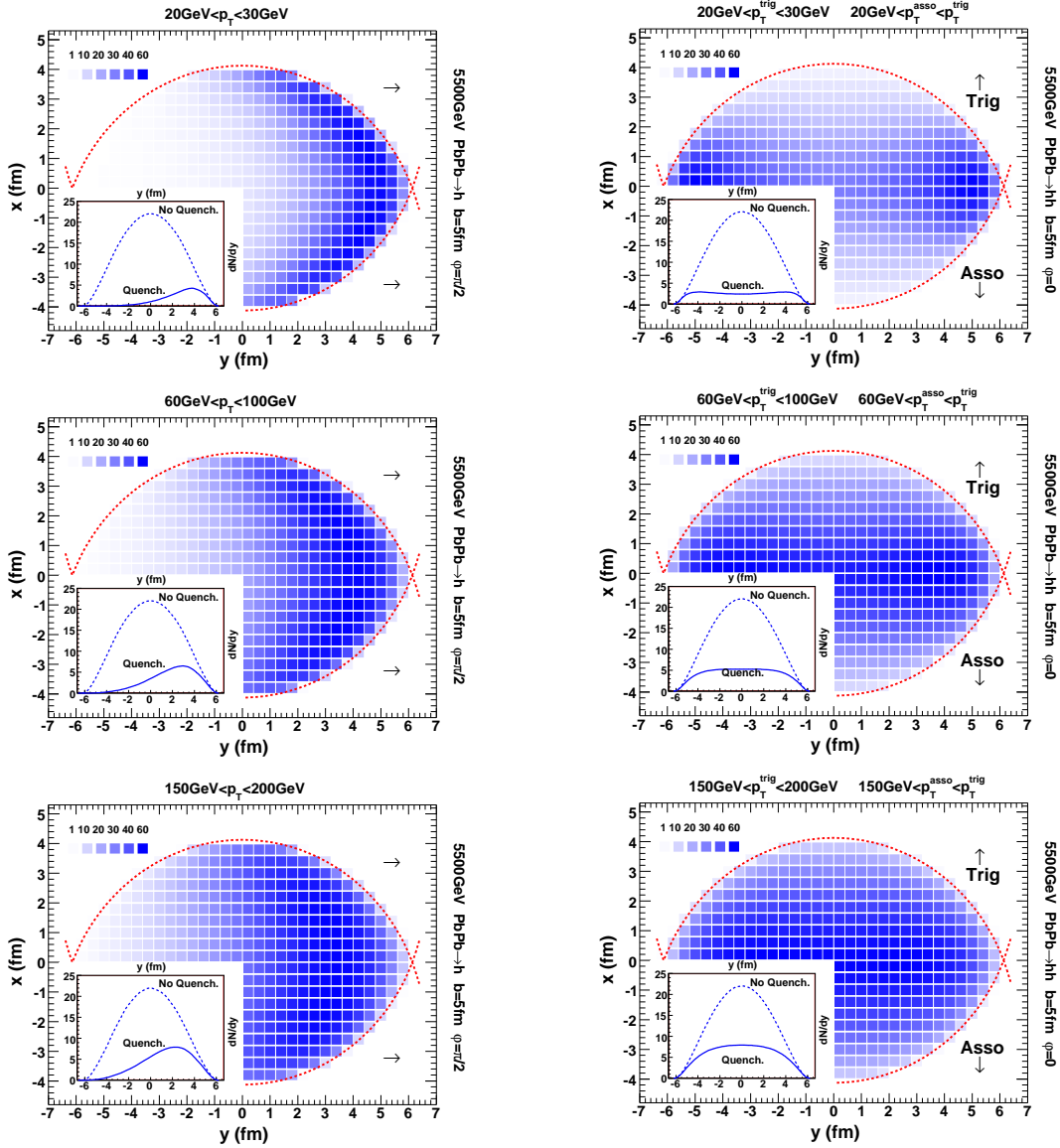


Figure 3. The same as Figure (2) but at the LHC energy.

hadron suppression factor is insensitive to shadowing at both the RHIC and LHC energy. Punch-through jets originate from the central region where the shadowing is stronger. Such jets at RHIC are greatly suppressed, so the dihadron suppression factor is also insensitive to the shadowing at RHIC. However, the punch-through jets at LHC are found to dominate dihadron spectra, so the dihadron suppression factor is sensitive to shadowing at LHC.

In summary, high p_T single and dihadron productions are studied within a NLO pQCD parton model with jet quenching in $A + A$ collisions at the RHIC/LHC energy. A simultaneous χ^2 -fit to both single and dihadron spectra can be achieved within their minima in the same narrow range of energy loss parameter for two different measurements. This fact provides a convincing evidence for jet quenching description. Punch-through jets are found to result in the dihadron suppression factor slightly more

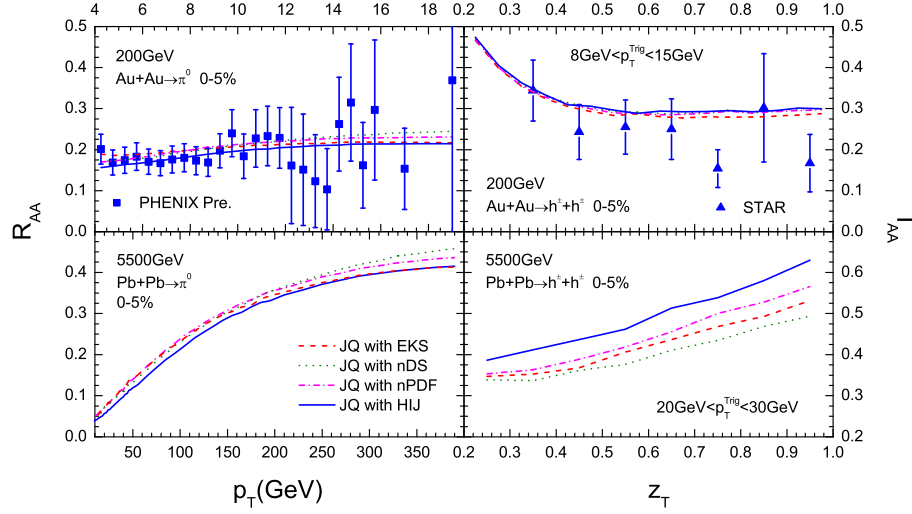


Figure 4. Four kinds of shadowing effects checked in the single and dihadron suppression factors at the RHIC/LHC energy. The data are from Ref. [10, 11].

sensitive to medium than the single suppression factor at RHIC. Such jets at LHC are found to dominate dihadron production with increasing dihadron transverse momentum, and therefore dihadron suppression is found to be more sensitive to different shadowing parameterizations of initial parton distributions at LHC.

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References

- [1] X.-N. Wang and M. Gyulassy, Phys. Rev. Lett. **68**, 1480(1992). Enke Wang and X.-N. Wang, Phys. Rev. Lett. **87**, 142301 (2001); Phys. Rev. Lett. **89**, 162301 (2002).
- [2] Xin-Nian Wang, Phys. Lett. B **595**, 165 (2004); **579**, 299 (2004); Phys. Rev. C, **70**, 031901 (2004).
- [3] Hanzhong Zhang, J. F. Owens, Enke Wang and Xin-Nian Wang, Phys. Rev. Lett, **98**, 212301 (2007); J. Phys. G, **34**, S801 (2007).
- [4] K. Adcox *et al.* [PHENIX Collaboration], Phys. Rev. Lett. **88**, 022301 (2002). C. Adler *et al.* [STAR Collaboration], Phys. Rev. Lett. **89**, 202301 (2002); Phys. Rev. Lett. **90**, 082302 (2003).
- [5] J. Adams *et al.* [STAR Collaboration], Phys. Rev. Lett. **97**, 162301 (2006); A. Adare, *et al.* [PHENIX Collaboration], Phys. Rev. C, **77**, 011901 (2008); arXiv: nucl-ex/0801.4545v1.
- [6] K. J. Eskola, V.J. Kolhinen and C.A. Salgado, Eur. Phys. J., **C9** (1999) 61.
- [7] D. de Florian, R. Sassot, Phys. Rev. D, **69**, (2004) 074028.
- [8] M. Hirai, S. Kumano, and T.-H. Nagai, Phys. Rev. C, **70**, (2004) 044905.
- [9] Shi-Yuan Li and Xin-Nian Wang, Phys. Lett. B, **527**, (2002)85-91.
- [10] Y. Akiba, Nucl. Phys. A **774**, 403 (2006).
- [11] S. S. Adler *et al.* [PHENIX Collaboration], Phys. Rev. C. **76**, 034904 (2007).